Minimum effective thickness for activation and low total electron yield of TiZrV NEG coatings.

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Abstract

Minimising the thickness of TiZrV non-evaporable getter (NEG) coatings is mandatory for increasing single-bunch instability thresholds in the proposed FCC-ee high luminosity lepton collider. After thermal activation the NEG surface is depleted of its O content and the maximum total electron yield (TEY) decreases to values close to 1.1. The effect of reducing the thickness of NEG coatings on activation performance, number of possible activation cycles and TEY is investigated. Substrates of oxygen-free electronic (OFE) copper are coated with TiZrV at thicknesses of 1100 nm, 200 nm, 90 nm and 30 nm. Coated samples are then heated to temperatures of up to 250°C in ultra-high vacuum and their surface chemistry is monitored with X-ray photoelectron spectroscopy (XPS), then TEY is measured using primary electrons with energies of up to 1600 eV. XPS measurements show a degraded activation with repeated cycling, and the effect is amplified for thinner NEG coatings and for shorter activation times. TEY measurements exhibit a decrease in the electron yield that is less effective for thinner coatings only after repeated activation cycles. These effects are linked to the delayed diffusion of O away from the surface due to accumulation of higher O concentrations in the film volume, an effect that is faster for thinner films.

Motivation

NEG coatings are widely used in particle accelerator vacuum chambers to provide distributed pumping speed, to reduce total electron yield of the chamber walls, and to reduce stimulated desorption. These effects rely on an effective thermal activation process. In the FCC-ee design NEG coatings are required, however the typical 1 µm thick film has a resistive wall impedance that is responsible for low single-bunch instability thresholds in both transverse and longitudinal planes, thus excluding the coating’s application. A possible solution to reduce the resistive wall impedance contribution is to decrease the coating thickness [1].

Diffusion and Activation

NEG activation is a diffusion limited process. The native oxide at the surface of the film must migrate away from the surface to leave an active metallic surface. Diffusion is driven by: temperature & time, diffusivity of the material, and gradient effects. Diffusion will be encouraged to flow across a steep gradient from high to low concentration zones. In this case high concentration at the surface, to low concentration in the sub-surface of the film. This is the major limiting factor for activation of very thin NEG coatings.

XPS

XPS observations show surface composition, including O and C, and is sensitive to the oxidation state of Ti, Zr and V. Typical collected signals from Ti, Zr and V on the surface of a NEG coating are shown below, for as-deposited and activated states.

Depth profile XPS

Film thicknesses of 1100 nm, 200 nm, 90 nm and 30 nm were deposited on chemically polished Cu samples by magnetron sputtering in a cylindrical magnetron system. Interwoven 3 mm diameter wires of Ti, Zr and V were used as a cathode, and sputtered with a Kr working gas at a pressure of around 2.1x10⁻³ mbar. The stainless steel vacuum chamber was 95 mm in diameter and 1.5 m long, positioned in the centre of a solenoid providing a 200 G magnetic field. Samples were mounted at 46 mm from the cathode. Film composition was measured to be 25% Ti, 40% Zr, and 35% V.

Deposition Conditions

Typical collected concentration of O in thin films is responsible for lower D reduction and high TEY.

Activation Performance and Maximum TEY: 4th Activation Cycle

Conclusions

The minimum effective thickness for activation of TiZrV NEG coatings was examined using XPS. Samples as thin as 30 nm were able to digest O and C, however after four short activation cycles were unable to activate effectively and this lead to a high maximum TEY of 1.6. Longer activation cycles extended the effective activation process and led to better activation and a lower TEY of 1.21 after the fourth cycle. The minimum effective thickness for use in an accelerator depends on the desired number of venting and activation cycles required.

Reduced activation performance is due to elevated concentrations of O in the film, which is higher for repeated activations and thinner films.

Future Work

Photon stimulated desorption measurements are planned for a thin NEG coating, to ensure desorption effects are not a limitation for minimum thickness.

Further experimentation is recommended for a film thickness around 150 nm, a film thickness that balances the limitations of activation and impedance. This thickness should be tested up to 10 activation and venting cycles, to confirm effective activation and low TEY.